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Research on Supply Chain Decision Considering Exhibition Hall Phenomenon under Carbon Quota

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Abstract

Taking a single manufacturer with direct sales channels and a single retailer with only traditional channels as the research object, this paper analyzes the carbon quota pressure of manufacturers. The two decision-making subjects also consider the influence of consumers' reference quality behavior, showroom behavior and anti-showroom behavior on the pricing decision of supply chain members. The conclusions are as follows: (1) After the introduction of the carbon quota policy, the total carbon emission of the supply chain system is significantly lower than that without the carbon quota policy. In general, the profits of both manufacturers and retailers are higher in the absence of carbon quota policy than in the case of carbon quota policy. (2) Showroom behavior is beneficial to manufacturers, while anti-showroom behavior is beneficial to retailers. They can seize the consumer groups of showroom behavior and anti-showroom behavior, raise wholesale prices, direct sales prices and retail prices to maximize their own profits, and avoid losing the profits brought by these groups after the consumer groups of showroom behavior and anti-showroom behavior become stable over time. (3) Manufacturers' profits are inversely proportional to consumers' reference quality effect coefficient, and consumers' reference quality effect coefficient has no obvious influence on retailers' profits. However, in general, the profits of manufacturers and retailers are higher in the absence of carbon quota policy than in the case of carbon quota policy.

Keywords

Carbon Quota; Showrooming; Anti-showrooming; Supply Chain Decision Making; Stackelberg Game.

1. Introduction

The omnichannel operation model is not uncommon in contemporary market transactions, which provides consumers with multiple choices for shopping channels, leading to consumer showroom behavior and anti-showroom behavior. showroom behavior refers to consumers experiencing and observing products in offline stores before transferring to online stores for purchase. Anti-showroom behavior refers to consumers browsing digital information of products in online stores and then transferring to offline physical stores for purchase. However, regardless of the behavior of consumers, the above two behaviors will have a certain impact on market demand and thus affect the pricing decisions of supply chain members. Before consumers decide which channel to purchase, they will first decide whether to purchase the product. One of the influencing factors of this decision is the reference quality, which means that consumers' purchasing decisions are measured based on the expected quality of the product. When the reference quality is higher than the actual quality of the product, the purchasing desire decreases, and vice versa, the purchasing desire increases.

In addition, the excessive carbon emissions brought about by rapid development have caused various disasters such as frequent extreme weather events and deterioration of the ecological

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environment. Reducing carbon emissions has become one of the hot issues of social concern. The government has also made many efforts in this regard in response to the call, and the carbon limit policy is one of them. The effective carbon limit range is the key to implementing this policy. A high limit is not enough to inhibit enterprises from reducing carbon emissions, and a low limit cannot provide incentives for enterprises to reduce emissions. Therefore, the government needs to decide on an appropriate range of carbon quotas.

The existing research on supply chain pricing decisions, consumer reference quality effects, and consumer showroom behavior in the context of carbon emissions reduction has achieved a series of important results. In terms of supply chain pricing decision-making in the context of carbon emission reduction, Xu Gang et al. [1] studied the supply chain pricing decision-making problem of one manufacturer and two retailers under a carbon quota policy. The research of Zhou Xideng [2] shows that the market price change of carbon emission rights is positively correlated with the optimal retail price, the optimal direct selling price, emission reduction and wholesale price change. Liang Xi et al. [3] found the optimal unit for manufacturers in their research.The reduction of emissions is influenced by both the cost of carbon policies, the initial reduction of emissions by manufacturers, and consumer channel preferences. Guo Junhua et al. [4] analyzed the impact of carbon quotas and consumer carbon emission sensitivity coefficients on product retail prices and optimal carbon reduction emissions. In terms of the effect of consumer reference quality, Guowei Liu, Suresh P. Sethi et al. [5] used an exponential smoothing process of product historical quality to describe the reference quality when comparing and analyzing the impact of manufacturers' farsightedness behavior and nearsightedness behavior on their decisions. They found that nearsightedness behavior produces a higher quality price ratio than farsightedness behavior. Yanyan He et al. [6] found that when analyzing the equilibrium decisions of retailers with different sales channels under the influence of consumer reference quality effects, consumers tend to purchase products with lower quality and price when shopping online. Zhichao Zhang and Qing Zhang [7] analyzed the static and dynamic pricing strategies of closed-loop supply chains, and the results showed that time-varying quality dynamic pricing strategies characterized by reference quality are more suitable for long-term cooperative closed-loop supply chains. Peng Ma, Yeming Gong et al. [8] explored the pricing and quality decisions of closed-loop supply chain members, and the results showed that when the reference price parameter is relatively large and the reference quality parameter is relatively small, it is beneficial for manufacturers. Deqing Ma and Jinsong Hu et al. [9] linked product goodwill with reference quality and reference services, and explored the quality strategy of manufacturers and the service level strategy of retailers in the O2O environment with mutually beneficial behavior among supply chain members. In terms of consumer showroom behavior, Xu Mingxing et al. [10] considered the impact of consumer two-way free riding behavior on retailer service decisions in a dual channel supply chain under a unified pricing strategy. Wang Zhanqing et al. [11] explored the impact of consumer quality expectations on retail price competition in a market where both exhibition hall behavior and anti-exhibition hall behavior coexist. Wang Weihao et al. [12] considered the delay phenomenon in the study of exhibition hall phenomena and coordinated the supply chain through cost sharing contracts. Zhang Xiao et al. [13] considered consumer learning behavior in the exhibition hall behavior market and found that exhibition hall behavior exacerbates market competition, and consumer learning behavior affects retailer profits. Lei Qian et al. [14] studied whether value-added services and price matching strategies can alleviate showroom behavior and thus solve the problem of retailers' operational difficulties.

There have been many theoretical studies on the impact of policies such as carbon quotas, carbon taxes, carbon trading, and low-carbon subsidies on supply chain decision-making. However, there is currently relatively little theoretical research considering the effects of consumer reference quality, exhibition hall behavior, and anti-exhibition hall behavior in the

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context of carbon quota policies. Therefore, the research focuses on single manufacturers who open direct sales channels and single retailers who only have traditional channels, Analyzing the carbon limit pressure on manufacturers, and considering the reference quality behavior of consumers, exhibition hall behavior, and anti-exhibition hall behavior simultaneously, has a positive impact on the pricing decisions of supply chain members.

2. Problem Description and Model Construction

2.1. Scenario 1: Carbon Quota Policy Situation

Taking a supply chain composed of a single manufacturer and a single retailer as the research object, analyze the supply chain under the background of carbon quotas Equilibrium decisions should be made by chain members when considering consumer showroom behavior, counter showroom behavior, and reference quality effects. The meanings of the letters used in the text are shown in Table 1, and the supply chain structure is shown in Figure 1.

Table 1. Table of letters and meanings

Q	Total market demand	c	Manufacturer's production costs
δ	Cross price elasticity coefficient	Dr	The demand for traditional channels
a	The proportion of loyal consumers in manufacturers' direct sales channels	Dd	The demand for direct sales channels
1-a	Proportion of loyal consumers in traditional channels	q	Actual product quality
w	trade price	rq	Consumer reference quality for products
pr	Traditional channel retail price	β	Consumer reference quality effect coefficient
pd	Direct Selling Channel Direct Selling Price	πr	Retailer profit
E	Carbon quotas set by the government	πm	Manufacturer's profit

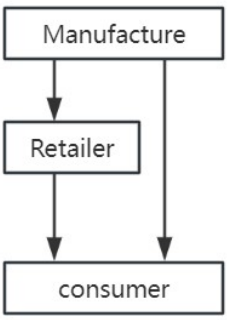

Figure 1. Supply Chain Structure Diagram

According to Krishnan H [15], assuming s represents the sales effort level of the retailer, when the retailer's sales effort reaches s, s new consumers will enter the market. Among the s consumers who entered the market, t proportion of consumers had exhibition hall behavior and anti-exhibition hall behavior. Among t proportion of consumers, m proportion of consumers had exhibition hall behavior, and 1-m proportion of consumers had anti-exhibition hall behavior.

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The cost of sales effort: $C_r = \frac{ks^2}{2}$

According to the above, the demand function for traditional channels and direct sales channels can be expressed as follows:

$$D_r = aQ - p_r + \delta p_d + (1-m)ts \tag{1}$$

$$D_d = (1-a)Q - p_d + \delta p_r + \beta\left(q - r_q\right) + mts \tag{2}$$

The profit function of retailers and manufacturers can be expressed as:

$$\pi_r = (p_r - w)D_r - \frac{ks^2}{2} \tag{3}$$

$$\pi_m = (p_d - c)D_d + (w - c)D_r \tag{4}$$

The carbon emissions of a manufacturer can be expressed as:

$$E_m = (D_d + D_r)e \tag{5}$$

Backward induction method is used to solve the problem. From $\frac{\partial^2 \pi_r}{\partial p_r^2} < 0$, it can be seen that the retailer has the optimal solution. By first order condition. Equal to 0 can obtain the optimal response function for the retail price of traditional channels, and by incorporating this response function into the manufacturer's profit function and manufacturer's carbon emissions function, it can be inferred that π $(w, p\ d)$ has a negative definite Hesse matrix for w, p_d.

Secondly, solving inequality optimization problems.

$$\begin{aligned} &\max_{w,p_d} \ \pi_m(w, p_d) \\ &s.t. \ \ E_m(w, p_d) \le E \end{aligned} \tag{6}$$

Solve inequality optimization problems by constructing Lagrange functions.

$$L(w, p_d, r_1) = \pi_m(w, p_d) + r_1\left(E - E_m(w, p_d)\right) \tag{7}$$

After solving, the optimal price p_m^*,and wholesale price w^* of the manufacturer's electronic channel can be obtained, and then the retail price p_r^* can be determined.

$$\begin{aligned} p_d^* = &\frac{[2st(m-1) - 2aQ]\delta^2 + \left[3\beta\left(r_q - q\right) + st(2m-5) - Q(2a+3)\right]\delta}{2(\delta+3)(\delta+1)(\delta-1)} \\ &+ \frac{-ts(4m+1) + Q(4a-5) + 5\beta\left(r_q - q\right)}{2(\delta+3)(\delta+1)(\delta-1)e} + G \end{aligned} \tag{8}$$

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$$w^* = K + \frac{[(r_q - q)\beta - ts - Q]\delta^2}{2(\delta+3)(\delta+1)(\delta-1)} + \frac{+2\beta(r_q - q) - 2(a+1)Q + 2st(m-2)}{2(\delta+3)(\delta+1)(\delta-1)} + G \quad (9)$$

$$p_r^* = K + \frac{[2(r_q - q)\beta + 2(a-1)Q - 2mts]\delta^2}{2(\delta+3)(\delta+1)(\delta-1)} + \frac{+(r_q - q)\beta - (4a+1)Q + ts(4m-5)}{2(\delta+3)(\delta+1)(\delta-1)} + \frac{(\delta+1)}{2}G \quad (10)$$

$$r_1 = \frac{M}{(\delta+3)(\delta-1)e} + \frac{4E}{(\delta+3)(\delta-1)e^2} \quad (11)$$

Among them, $K = \frac{\left[5(r_q-q)\beta+(2a-5)Q-2st(m+\frac{3}{2})\right]\delta}{2(\delta+3)(\delta+1)(\delta-1)}$, $M = [ts(m-1) - aQ - 2c]\delta - c\delta^2 - ts(m+1) + 2(r_q - q)\beta + (a-2)Q + 3c$, $G = \frac{4E(\delta+1)}{2(\delta+3)(\delta+1)(\delta-1)e}$.

When r_1=0, the inequality constraint does not work. When r_1>0, the inequality constraint works, that is:

$$\mathrm{E} < \frac{\mathrm{Me}}{4} = \Delta\mathrm{u}(1)$$

According to $D_r > 0, D_d > 0$,then:$E > \frac{e|-2mst+2Qa+st-Q+\ (r_q-q)|}{2} = \Delta d(1)$.

2.2. Scenario 2: No Carbon Limit Policy Scenario

The demand function of traditional channels for retailers and direct sales channels for manufacturers, as well as the profit function of the two supply chain entities, are the same as Scenario 1 under the absence of carbon limit policies, except that there is no carbon emission limit, meaning that enterprises do not need to worry about carbon emissions. The inverse solution method can be used to obtain an equilibrium solution.

$$w^* = X\delta + Y + Z \quad (12)$$

$$p_d^{**} = X + Y + Z\delta \quad (13)$$

$$p_r^* = \frac{(1+\delta)Y + 2Z + 2X\delta}{2} \quad (14)$$

Among them, $X = \frac{[(r_q-q)\beta-mst+(a-1)Q]}{2\delta^2-2}$, $Y = \frac{c(\delta^2-1)}{2\delta^2-2}$, $Z = \frac{[(m-1)ts-aQ]}{2\delta^2-2}$.

3. Model Analysis

Proposition 1: The effective range of carbon limit is $\Delta d(1) < E < \Delta u(1)$.

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Proposition 1 indicates that if the carbon emissions generated by a company for each unit of product produced are e, the maximum carbon emission limit should always be Δu (1), and the company should be allowed to have at least Δd (1) of carbon emissions. The government should observe the market share of the main carbon emitting entities in the supply chain when setting the minimum carbon emission limit. It is necessary to ensure that enterprises have a minimum carbon emission to ensure that the demand of the supply chain entities is greater than zero.

Proposition 2: In two cases, the direct sales price and wholesale price of the manufacturer's direct sales channel are subject to exhibition hall behavior and reverse exhibition. The proportion of consumers engaged in exhibition hall behavior increases, and the retail prices of traditional channels for retailers increase with the proportion of consumers engaged in exhibition hall behavior and counter exhibition hall behavior.

Proofs:(1)$\frac{\partial w^*}{\partial t} = \frac{s(\delta^2+2m\delta+3\delta-2m+4)}{2(1-\delta)(\delta+1)(\delta+3)} > 0$; $\frac{\partial w^{**}}{\partial t} = \frac{s(m\delta-m+1)}{2(1-\delta)(\delta+1)} > 0$.

(2)$\frac{\partial p_d^*}{\partial t} = \frac{s(2m\delta^2-2\delta^2+2m\delta-5\delta-4m-1)}{2(\delta-1)(\delta+1)(\delta+3)} > 0$; $\frac{\partial p_d^{**}}{\partial t} = \frac{s(m+\delta-m\delta)}{2(1-\delta)(\delta+1)} > 0$.

(3)$\frac{\partial p_r^*}{\partial t} = \frac{s(2m\delta^2+2m+3\delta-4m+5)}{2(1-\delta)(\delta+1)(\delta+3)} > 0$; $\frac{\partial p_r^{**}}{\partial t} = \frac{s(m\delta^2-\delta^2+2m\delta-3m+3)}{4(1-\delta)(\delta+1)} > 0$.

Regardless of whether the government implements a carbon quota policy or not, consumer showroom behavior is always beneficial for manufacturers to obtain profits from direct sales channels, while anti showroom behavior is always unfavorable for manufacturers to obtain profits from direct sales channels. Therefore, in both cases, the increase in manufacturer's direct selling price with an increase in t indicates that exhibition hall behavior has a greater impact on improving manufacturer's profits than anti exhibition hall behavior has a greater impact on reducing manufacturer's profits. In addition, manufacturers continue to increase wholesale prices with the aim of preserving the showroom behavior of direct sales channels for consumers, thereby inhibiting retailers from allocating excessive supply chain system profits. Another reason why manufacturers increase wholesale prices under the carbon quota policy scenario is that the carbon quota policy increases manufacturers' production costs. If they want to make profits as soon as possible, they must take both traditional and direct sales channels into account. In both cases, retailers will increase their retail prices in order to maintain market profits when facing sudden increases in wholesale costs.

Proposition 3: In both cases, an increase in the proportion of consumers in exhibition hall behavior will prompt manufacturers to make decisions to lower wholesale prices and increase direct sales prices, prompting retailers to lower traditional channel retail prices.

Proof: (1)$\frac{\partial w^*}{\partial m} = -\frac{st}{(\delta+3)(\delta+1)} < 0$, $\frac{\partial w^{**}}{\partial m} = -\frac{st}{2(\delta+1)} < 0$.

(2)$\frac{\partial p_d^*}{\partial m} = \frac{(\delta+2)st}{(\delta+3)(\delta+1)} > 0$,$\frac{\partial p_d^{**}}{\partial m} = \frac{st}{2(\delta+1)} > 0$.

(3)$\frac{\partial p_r^*}{\partial m} = -\frac{(\delta+2)st}{(\delta+3)(\delta+1)} < 0$,$\frac{\partial p_r^{**}}{\partial m} = -\frac{st(\delta+3)}{4(\delta+1)} < 0$.

In the context of carbon quota policies, manufacturers face a relatively high cost situation. Reducing wholesale prices while increasing direct selling prices is the key to manufacturers' profits. In order to cope with the adverse impact of exhibition hall behavior on retailers, reducing retail prices is an effective means for retailers to maintain market competitiveness. In the absence of carbon quotas, manufacturers face less cost pressure, but still choose to lower wholesale prices because exhibition hall behavior always promotes manufacturers' profits and suppresses retailers' benefits. Manufacturers consider that retailers will adopt a low profit and high sales strategy due to the increase in exhibition hall behavior, so lowering wholesale prices promotes retailers' purchases. The more consumers retailers attract, the greater the likelihood of exhibition hall behavior occurring, This is a roundabout way for manufacturers to use offline experience services from retailers to promote showroom behavior.

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Combining Proposition 2 and Proposition 3, it can be inferred that consumer anti showroom behavior has an impact on supply chain decision-makers. Consumer anti showroom behavior will promote an increase in retailers' profits. Therefore, when anti showroom behavior increases, retailers are bound to increase retail prices, while manufacturers may lower direct selling prices and increase wholesale prices to suppress retailers from allocating excessive overall supply chain profits.

Proposition 4: In both cases, the reference quality effect has the same impact on the manufacturer's wholesale price and direct selling price, as well as the retailer's traditional channel retail price. When the actual quality of the product is higher than the reference quality, the manufacturer's wholesale price and direct selling price, as well as the retailer's traditional channel retail price, will increase with the consumer's sensitivity to the reference quality. On the contrary, it decreases.

Proof:(1)When the actual quality of the product is higher than the reference quality, $\frac{\partial w^*}{\partial \beta} = \frac{(\delta^2+5\delta+2)(q-r_q)}{2(1-\delta)(\delta+3)(\delta+1)} > 0$, When the actual quality of the product is below the reference quality, $\frac{\partial w^*}{\partial \beta} = \frac{(\delta^2+5\delta+2)(q-r_q)}{2(1-\delta)(\delta+3)(\delta+1)} < 0$; When the actual quality of the product is higher than the reference quality, $\frac{\partial w^{**}}{\partial \beta} = \frac{(q-r_q)}{2(1-\delta)(\delta+1)} > 0$, When the actual quality of the product is below the reference quality, $\frac{\partial w^{**}}{\partial \beta} = \frac{(q-r_q)}{2(1-\delta)(\delta+1)} < 0$.

(2)When the actual quality of the product is higher than the reference quality, $\frac{\partial p_d^*}{\partial \beta} = \frac{(3\delta+5)(q-r_q)}{2(1-\delta)(\delta+3)(\delta+1)} > 0$, When the actual quality of the product is below the reference quality, $\frac{\partial p_d^*}{\partial \beta} = \frac{(3\delta+5)(q-r_q)}{2(1-\delta)(\delta+3)(\delta+1)} < 0$; When the actual quality of the product is higher than the reference quality, $\frac{\partial p_d^{**}}{\partial \beta} = \frac{(q-r_q)}{2(1-\delta)(\delta+1)} > 0$, When the actual quality of the product is below the reference quality, $\frac{\partial p_d^{**}}{\partial \beta} = \frac{(q-r_q)}{2(1-\delta)(\delta+1)} < 0$.

(3)When the actual quality of the product is higher than the reference quality, $\frac{\partial p_r^*}{\partial \beta} = \frac{(2\delta^2+5\delta+1)(q-r_q)}{2(1-\delta)(\delta+3)(\delta+1)} > 0$, When the actual quality of the product is below the reference quality, $\frac{\partial p_r^*}{\partial \beta} = \frac{(2\delta^2+5\delta+1)(q-r_q)}{2(1-\delta)(\delta+3)(\delta+1)} < 0$; When the actual quality of the product is higher than the reference quality, $\frac{\partial p_r^{**}}{\partial \beta} = \frac{(q-r_q)\delta}{2(1-\delta)(\delta+1)} > 0$, When the actual quality of the product is below the reference quality, $\frac{\partial p_r^{**}}{\partial \beta} = \frac{(q-r_q)\delta}{2(1-\delta)(\delta+1)} < 0$.

Regardless of whether the government formulates a carbon quota policy or not, consumers will engage in reference quality behavior during market transactions. Therefore, the impact of reference quality effects on pricing decisions of supply chain members is basically the same in both cases, with the key point being the difference between actual product quality and reference quality. On the other hand, the low-carbon products produced by manufacturers under the carbon quota policy have to some extent improved the quality level. Therefore, manufacturers will also increase wholesale and direct selling prices, and retailers will correspondingly increase retail prices.

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4. Numerical Analysis

To further validate the previous analysis, under a carbon free policy, manufacturers do not need to be overly concerned about the amount of carbon emissions from their products. At this time, the cost is relatively low compared to the carbon limit policy scenario, and the carbon emissions per unit of product are relatively high,

Assuming that the parameters Q=500, a=0.7, δ=0.5, k=0.01, s=100, t=0.5, q=8, r q are taken= 10, c=200, e=50, simulate the changes in profits of manufacturers and retailers with m and β under a carbon free quota policy.

Under the carbon quota policy, manufacturers will actively take measures such as technological innovation to reduce carbon emissions per unit of product as much as possible. Assuming that after technological innovation, manufacturers produce 25 units of carbon dioxide and other gases per unit of product. As people are more sensitive to similar losses than benefits, it is assumed that the actual quality of products is lower than the reference quality of consumers. Taking Q=500, a=0.7, δ=0.5, k= 0.01, s=100, t=0.5, q=8, r q=10, c=200, e=25, then based on the previous calculation results, it can be concluded that The effective carbon limit range is [2395.00351.25], taking E=3500 to simulate the changes in profits of manufacturers and retailers with m and β under the carbon limit policy.

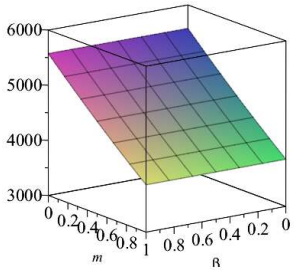

Figure2. The change of retailer profit with m, β under no carbon quota policy

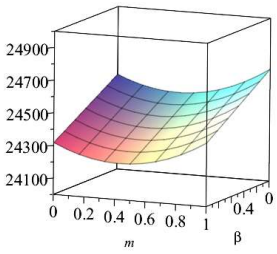

Figure 3. The change of manufacturer's profit with m, β under no carbon quota policy

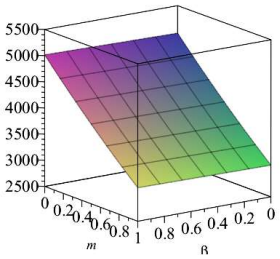

Figure 4. The change of retailer profit with m, β under carbon quota policy

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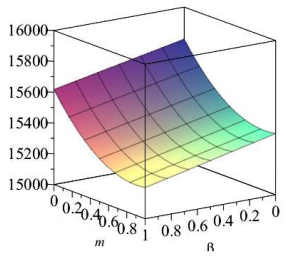

Figure 5. The change of manufacturer's profit with m, β under carbon quota policy

Figure3 The change of manufacturer's profit with m, β under carbon quota policyFigures 2 and 3 indicate that regardless of whether carbon quota policies are implemented or not, exhibition hall behavior always reduces retailer profits, Although the gap between the actual quality of products and the reference quality of consumers has narrowed under the carbon quota policy, which means that the reference quality effect promotes consumers' purchasing tendencies, it has not played a significant role in improving retailers' profits. Figures 4 and 5 indicate that the interaction between consumer showroom behavior and reference quality behavior leads to the lowest point of manufacturer profits in both cases, showing a trend of first decreasing and then increasing. The effect of consumer reference quality does not suddenly appear or disappear due to the introduction of carbon quota policies, but only changes as manufacturers respond to carbon quota policies to produce high-quality low-carbon products. When the exhibition hall phenomenon is not obvious, the negative impact of consumer reference quality effect under carbon free quota policies is greater than the positive impact of exhibition hall phenomena, resulting in a decrease in manufacturers' profits, Although the quality of low-carbon products produced by manufacturers under the carbon quota policy is relatively high, their profits may still decrease. This may be due to the increased advertising and promotion of low-carbon products in the market, which increases consumers' expectations of low-carbon products and increases the gap between consumers' perceived quality and actual product quality, thereby causing a backlash against manufacturers' profits. With the passage of time, while the level of product quality remains unchanged, consumers' expected quality of products gradually stabilizes over time, and the impact on manufacturers' profits also gradually stabilizes. However, the widespread popularity of exhibition hall phenomenon in the market has gradually increased its impact on improving manufacturers' profits. Therefore, The promotion effect of exhibition hall phenomenon on manufacturers' profits will gradually exceed the stable impact of reference quality effect on manufacturers, therefore, the profits of manufacturers will increase in both cases.

In addition, due to the assumption in the numerical simulation that the carbon limit E set by the government is 3500, the carbon emissions of manufacturers under the carbon limit policy are 3500. However, under the same parameter assumption without the carbon limit policy, the carbon emissions of manufacturers are 119864;m=(119863;r+ 119863;d) * 50=7652.50> 3500. Here, only the parameters m=0.5 and β=0.7 are taken as examples, The remaining parameter values are the same as the parameter values taken for the carbon quota policy scenario, but after calculation, even if m=0.1 and β=0.1, the carbon emissions of the supply chain under the carbon quota policy are still around 7000, which is greater than the carbon emissions under the carbon quota policy. It can be seen that the introduction of carbon quota policies has indeed reduced the carbon emissions of the supply chain.

The previous article explored the comprehensive impact of exhibition hall behavior and consumer reference quality effects on the profits of supply chain entities, but has not yet analyzed the impact of exhibition hall behavior and counter exhibition hall behavior on the profits of manufacturers and retailers. The following parameter $t \in$ [0.2,0.8] is taken for analysis.

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Table 2. Changes of manufacturers' and retailers' profits with t under carbon quota policy

t	w^*	p_d^*	p_r^*	π_r^*	π_m^*
0.2	377.22	311.35	445.45	4605.14	20083.32
0.3	387.03	321.83	454.97	4566.23	21485.87
0.4	396.84	332.30	464.50	4527.49	22888.87
0.5	406.65	342.78	474.02	4488.91	24292.12
0.6	416.46	353.26	483.54	4450.49	25695.82
0.7	426.27	363.73	493.07	4412.24	27099.89
0.8	436.08	374.21	502.59	4374.15	28504.35

Table 3. The change of manufacturer's and retailer's profit with t under no carbon quota policy

t	w^{**}	p_d^{**}	p_r^{**}	π_r^{**}	π_m^{**}
0.2	392.87	325.73	457.87	4175.00	20306.65
0.3	397.87	330.73	464.12	4339.06	21596.53
0.4	402.87	335.73	470.37	4506.25	22930.15
0.5	407.87	340.73	476.62	4676.56	24307.53
0.6	412.87	345.73	482.87	4850.00	25728.65
0.7	417.87	350.73	489.12	5026.56	27193.53
0.8	422.87	355.73	495.37	5206.25	28702.15

Tables 2 and 3 list the changes in decision variables and profits of supply chain decision-makers with t in two scenarios. It is found that in both cases, the manufacturer's direct selling price, wholesale price, and retail price of retailers increase with t. The carbon quota policy introduced by the government exerts pressure on manufacturers to use technological innovation and other means to produce products with lower carbon emissions, which to some extent increases the production costs of manufacturing. In response, wholesale prices and direct sales prices have also increased to some extent. With the widespread prevalence of exhibition hall and counter exhibition hall phenomena, manufacturers and retailers will wait for opportunities to increase prices, thereby increasing their own profits. But as time passes, if the market reaches saturation and the consumer group of showroom behavior and anti showroom behavior stabilizes, the profits of manufacturers and retailers will not continue to increase with the increase of t. Under the policy of no carbon limit, the continuous increase of t means that the consumer group of showroom behavior that is beneficial to manufacturers is increasing, and the consumer group of counter showroom behavior that is beneficial to retailers is increasing. Moreover, manufacturers are no longer concerned about carbon emission restrictions. Therefore, seizing the increasing consumer group and implementing measures to increase prices for them is the best choice for manufacturers and retailers to obtain as much profit as possible, As a result, manufacturers' profits are showing a continuous upward trend, and retailers' profits are also constantly rising.

5. Conclusion

The quality effect of consumer reference, showroom behavior, and counter showroom behavior are important factors that cannot be ignored in influencing consumer purchasing decisions, and are also important components that affect supply chain decision-makers in formulating pricing strategies. Self bicarbon order Since the proposal of the standard, the government has introduced policies such as carbon quotas, carbon taxes, carbon trading, and low-carbon

subsidies to reduce carbon emissions in the supply chain system. Relevant theoretical research has also achieved considerable results. However, currently, there is relatively little theoretical research considering consumer reference quality effects, exhibition hall behavior, and anti exhibition hall behavior in the context of carbon quota policies. Therefore, Taking a single manufacturer with open direct sales channels and a single retailer with only traditional channels as the research objects, this study analyzes the carbon limit pressure on manufacturers. The two decision-making entities simultaneously consider the impact of consumer reference quality behavior, exhibition hall behavior, and anti exhibition hall behavior on the pricing decisions of supply chain members. The final conclusion is as follows: (1) The government should observe the market share of the main carbon emitting entities in the supply chain when setting the minimum carbon emission limit. It is necessary to ensure that enterprises have a minimum carbon emission to ensure that the demand of the supply chain entities is greater than 0. If the manufacturer's unit carbon. If the emission is e, the government can set the carbon limit within the range of $\Delta\ d\ (1)<E<\Delta\ u\ (1)$. And numerical points. The analysis shows that after the introduction of carbon quota policies, the total carbon emissions of the supply chain system are significantly lower than those without carbon quota policies. (2) Exhibition hall behavior is beneficial to manufacturers, while anti exhibition hall behavior is beneficial to retailers. Both can capture the consumer groups of exhibition hall behavior and anti exhibition hall behavior, increase wholesale prices, direct sales prices, and retail prices to maximize their own profits, and avoid losing profits brought by exhibition hall behavior and anti exhibition hall behavior as the consumer group stabilizes over time. (3) The manufacturer's profit is inversely proportional to the consumer reference quality effect coefficient, and the consumer reference quality effect coefficient has no significant impact on the retailer's profit. But overall, manufacturers and retailers' profits are higher in the absence of carbon limit policies than in the case of carbon limit policies.

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